Solar Thermal Power Generation Using Seebeck Effect

Shagufta Jawaid and M.Ammar Akbar

Department of Electrical Engineering, Bahria University
Karachi, 75260, Pakistan (gmjacs@gmail.com)

Abstract: Energy has always been the most essential part of human race. Due to the declination of natural fuels and fossil fuels, the need to bring out system which are reliable and replenish is very important. The renewable energy sources such as sunlight, wind, geothermal heat ,tides and biomass are cheap to operate due to their replenish behavior in nature. The testing out new designs with the fusion of solar thermal energy and thermoelectric energy conversion using Seebeck Effect, is one of the remarkable technologies which have great potential to play a significant role in the energy requirements in the near future. This technology directly converts solar energy to electricity using thermo-electric generator modules (TEGs).

In this project the solar parabolic dish concentrator concentrates the solar heat energy to create hot-end whereas cold-end temperature is kept down by means of water flow. A six feet (1.8m diameter) parabolic dish concentrator consist of plane mirrors concentrates solar heat to the aluminum receiver, which has two sides one is hot side and another is cold side. Thermo-electric generator modules (TEGs) consists of bismuth telluride ($Bi_2 Te_3$) semiconductor. The two axis linear solar tracking system is designed to increase the overall efficiency of the system. Solar thermal energy collecting system comprising of parabolic dish concentrator to achieve a temperature gradient of 270 °C between hot and cold side of the receiver which was expected to produce 14.7 W per thermo-electric generator module. Multiple modules can be used to generate power up to 500W and the efficiency can be maintained by keeping the temperature difference .The relationship of solar thermal energy and thermo-electric energy conversion bring out to generate clean energy.

Keywords: solar parabolic dish concentrator, See-beck effect, thermo-electric module, receiver.

I. INTRODUCTION

The new era of renewable energy sources making remarkable effort to eradicate the environmental damage and shortage of natural fuels due to its rapid consumption. The availability of solar energy is free of cost. Thermo-electric energy conversion using Seebeck effect, is one of the remarkable technologies which have great potential to play a vital role in the eradication of energy crisis. This technology directly converts solar energy to electricity using thermo-electric generator modules (TEGs). Seebeck is the phenomenon observed when temperature difference is created across dissimilar metal junctions which results in electric potential difference. It is the application of temperature difference to electric voltage generation. This effect can be used to generate electricity, maintaining temperature difference across the two junction of the semiconductors. Thermoelectric devices can utilize solar thermal power or surplus heat energy to generate electricity and are extremely friendly to the environment.

II. DESIGN AND METHODOLOGY

Solar thermal power generation system have a potential to play important role in the generation of electric power having environment friendly system. The solar parabolic dish and thermoelectric generator principle is integrating the receiver on the focal region of parabolic dish concentrator to deliver electrical energy for local needs. The design is based on the simple satellite dish having reflecting surface by placing array of mirrors on it. This reflecting surface reflects the sunlight onto the receiver to increase temperature upto `300◦C on the hot side of the thermoelectric generator module, the cold side temperature will be kept 30◦C by channeling water across the receiver. The dual axis solar tracking system is being made to track the sun all day long for maximum and optimum result. The dc-dc converter is designed to provide smooth ripple free electric power.

The design challenges comprised of two things

1. Solar parabolic dish concentrator
2. Thermo-electric generator receiver

The factual relationship between these two components will lead to a system which generate enough power of our use.

A. Solar parabolic dish concentrator:

The system is designed to provide the temperature difference of 270 °C across the receiver by providing concentrating solar radiation to a focal point where the solar radiation start transforming into thermal energy. 1.8m diameter satellite dish have been to provide the enough concentration to the focal point which leads to the generation of enough power of our use.

The focal point of our solar parabolic dish concentrator is 0.7837m the requirement of the system is more than 300◦C temperature on the focal point to give maximum heat intensity to the object place on the focal point of solar parabolic dish concentrator.

B. Thermo-electric power generator

The receiver for solar parabolic dish reflector is designed by analyzing the heat transfer rate of different metals. The 10mm aluminum receiver plate consist of hot side thermo-electric generator module faces the focal point of parabolic concentration, while the other side of the plate temperature kept constant by channeling water across it. The width of the cold side of the receiver is 20mm, 5mm deep milled from the sides of the plate. The heat fins were milled each of 5mm deep from the front side of the hot plate of the receiver. The working phenomenon is when 270 °C temperature difference is achieved between the two faces of the receiver, results in generating potential difference at the output. The solar parabolic dish concentrator concentrates the radiation onto the receiver

And the receiver develops potential at the end.

Fig. 1.1 Receiver and Parabolic Dish

III. THERMODYNAMICS CALCULATION OF SOLAR DISH CONCENTRATOR

The measurement of the depth is taken by using tight fishing line across the dish and a rule to measure depth c.

f = Focal Length

c = Depth

D = Diameter

R = Focal Ratio

A= Effective Apperture of the dish

Diameter of the dish = 1.8 m

Depth of the dish = 0.2667m

Equation of focal length:

$$f = \frac{D^2}{16*c} \quad \text{———} (1)$$

$$f = \frac{1.8^2}{16*0.2667}$$

$$f = 0.759\ m$$

Effective apperture of the dish:

$$A = 0.6 * \frac{\pi D^2}{4} \quad \text{———} (2)$$

$$A = 0.6 * \frac{\pi 1.8^2}{4}$$

$$A = 1.5274\ m^2$$

Focal ratio of the dish:

$$R = \frac{f}{D} \quad \text{———} (3)$$

$$R = \frac{0.759}{1.8}$$

$$R = 0.4218$$

Specifications of the module:

Module No.	Hot Side Temp (C⁰)	Cold Side Temp (C⁰)	Output Voltage (V)	Output Current (A)	Power (W)	Heat flow Across Module W	Heat flow density wm^{-2}
TEG 12611-6.0	300 C^0	30 C^0	4.2 V	3.4 A	14.6 W	365 W	11.6

In order to acquire 500 watts, 35 modules are connected in series and parallel combination.

Per module power = 14.6 watts

No. of required modules = 35

Total power of 35 modules = per module power * No. of req modules – (4)

Total power of 35 modules = 14.6*35

Total power of 35 modules = 511watts

Per module heat flow ≈ 365 watts

Heat flow across 35 modules = No. of req modules*per module heat flow— (5)

Heat flow across 35 modules = 35*365 watts

Heat flow across 35 modules = 12775 Watts

10% of calculated heat flow = $\frac{12775\ W}{100} * 10$ —— (6)

10% of calculated heat flow=1277.5 watts

Total amount of heat flow=heat flow across modules*10% of calculated heat flow— (7)

Total amount of heat flow=12775+1277.5 watts

Total amount of heat flow=14052.5 watts

Reflectivity of low glass mirror = 89-90 %

$$A_{collector} = \frac{\text{Total heat flow across modules}}{\text{Maximum solar radiation reaches on earth}} \quad \text{——} (8)$$

$$A_{collector} = \frac{14052.5\ W}{1000\ wm^{-2}}$$

To find radius, we know that,

$$A_{collector} = \pi r^2 \quad \text{————} (9)$$

$$r^2 = \frac{14.0525}{\pi}$$

$$r = \sqrt{\frac{14.0525}{\pi}}$$

$r = 2.115$ m

$$D = 2 * r \text{ ———— } (10)$$

$$D = 2 * 2.115 \text{ m}$$

$$D = 4.23\text{m}$$

IV. IMPLEMENTATION

We step forward towards mechanical part, the designing of the strong structure which hold the six feet (1.8m) solar parabolic dish. Mechanical structure consist of 8inch steel pipe, which holds the whole weight of the solar parabolic dish, aluminum receiver, Dc gear motors, shafts, and pulleys. The designing of the two axis linear solar tracking system is very important to increase the efficiency of the system. To obtain optimization in the results we incorporated dual axis tracking system which rotate the dish and track the sun in two angles by means of dc gear motors.

The sun tracking angles are:-

A) Elevation tracking (horizontal tracking of dish concentrator)

B) Azimuth tracking (vertical tracking of dish concentrator)

When the solar radiations collect on the focal point the ambient temperature start increasing due to the concentrating solar rays. The heat collected on the focus starts to travel in the parallel fins of the receiver by which the heat transfer rate achieved is through this equation,

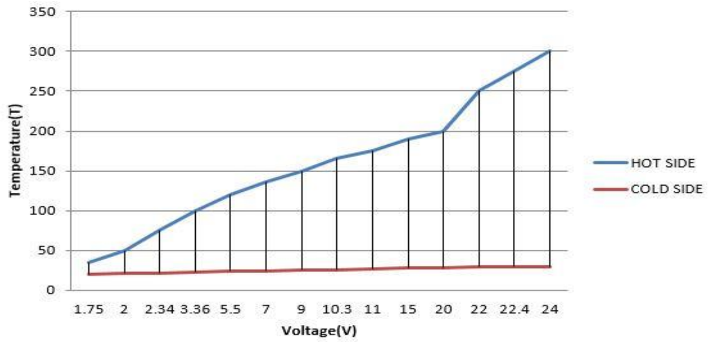
$$\frac{Q}{T} = \frac{KA(T_2 - T_1)}{d}$$

$\frac{Q}{T}$ is the heat transfer rate.

Fig. 1.2 Solar Parabolic Dish Concentrator

V. RESULTS AND DISCUSSIONS

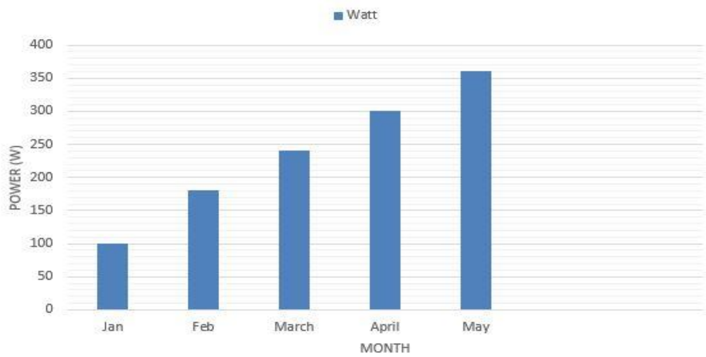
The design impilcations and the specification of the optimal power generating system is result of many experimentative procedures and quantative analysis.



Graph 1.1 relationship between temperature difference and voltages

The test conducted for five months. The ambient temperature in the start of the year is relatively low as compare to mid of the year. The temperature difference up to 100◦C across TEG is observed in January.

The temperature difference starts increasing as the temperature rise in the following months. Greater the temperature difference maintained, more power produced. As shown in the graph below:



Graph 1.2 Maximum power achieved in months

VI. CONCLUSION

The need of energy is increasing as the growth of population, scientific researches and requirement to build new technologies. The system on the renewable energy was carried out to experiment the role of thermo-electric module and solar thermal power generation system has also been illustrated.

The project involves 1.8m diameter parabolic dish reflector having an array of 4’4 mirror to concentrate the solar radiation onto the receiver. The receiver comprised of thermo-electric generation modules which produces voltage when get in contact with heat on the hot side and the cold side temperature will be kept low at 30C. Several tests have been conducted in order to achieved the require amount of ambient temperature. The overall efficiency the energy produced will be controlled and stored in batteries. To increase the efficiency of the overall system we have also installed a dual axis tracking circuit to track the sun in its peak hours.

VII. FUTURE RECOMMENDATION

The project had several aspects but there are some other advancement in this project which can play vital role in the modification and efficiency of the system. These points are as follows

- We have placed an array of square pieces of mirror on the solar parabolic dish concentrator. But different shapes of mirror can also be tested to achieve the high reliability of the concentration ratio.
- An intelligent solar tracker can also be implemented which can be programmed to do the task.
- To increase the overall efficiency, the water cooling tower should be fabricated without using dc battery to avoid the losses.

REFERENCES

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied&page=article&op=view&path%5B%5D=4136&path%5B%5D=2349

https://www.irjet.net/archives/V4/i6/IRJET-V4I679.pdf
https://www.epget.bme.hu/docs/Kutatas/Konferencia/expres2016/18_S_R_Pavlovic,V_P_Stefanovic,E_Bellos_EXPRES_2016.pdf

https://ieeexplore.ieee.org/document/8055565/metrics

https://www.tandfonline.com/doi/abs/10.1080/15567036.2011.578110

https://www.theclimategroup.org/sites/default/files/archive/files/Greenhouse-Indicator-Generation-Report-2009.pdfhttp://www.ftexploring.com/solar-energy/direct-and-diffuse-radiation.htm

https://www.researchgate.net/publication/263128579_Solar_Tracking_Sun_Tracking_Sun_Tracker_Solar_Tracker_Follow_Sun_Sun_Position

https://www.slideshare.net/mahfuzamansura/design-and-construction-of-automatic-dualaxis-solar-tracking-system-using-light-dependent-resistor-ldr-sensors